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2 *The Left Cradling Bias: An Evolutionary Facilitator of Social Cognition?*

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19 **Highlights**

- 20 1. LCB reflects an evolutionarily old behavioral bias for perceiving social stimuli
21 2. A pillow with a face symbol, but not a control stimulus elicited a LCB
22 3. Cradling side of an infant human doll interacted with social ability in children
23 4. An infant primate doll reversed the LCB
24 5. LCB reflects population level brain organisation and domain-specific function

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28 Declarations of interest: none
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Abstract

A robust left side cradling bias (LCB) in humans is argued to reflect an evolutionarily old left visual field bias and right hemisphere dominance for processing social stimuli. A left visual field bias for face processing, invoked via the LCB, is known to reflect a human population-level right cerebral hemisphere specialization for processing social stimuli. We explored the relationship between cradling side biases, hand dominance and socio-communicative abilities. Four and five year old typically-developing children (N = 98) participated in a battery of manual motor tasks interspersed by cradling trials comprising a(n): infant human doll, infant primate doll, proto-face pillow and no-face pillow. Mean social and communication ability scores were obtained via a survey completed by each child's key teacher. We found a population-level LCB for holding an infant human doll that was not influenced by hand dominance, sex, age or experience of having a younger sibling. Children demonstrating a LCB, did however, obtain a significantly higher mean social ability score compared with their right side cradling counterparts. Like the infant human doll, the proto-face pillow's schematic face symbol was sufficient to elicit a population-level LCB. By contrast, the infant primate doll elicited a population-level right side cradling bias, influenced by both hand dominance and sex. The findings suggest that the LCB is present and visible early in development and is likely therefore, to represent evolutionarily old domain-specific organisation and function of the right cerebral hemisphere. Additionally, results suggest that a LCB requires minimal triggering but can be reversed in some situations, possibly in response to species-type or levels of novelty or stress as perceived by the viewer. Patterns of behavioral biases within the context of social stimuli and their associations with cognitive ability are important for understanding how socio-communication abilities emerge in developing children.

Abbreviations:

Left cradling bias (LCB)

Key words:

behavioral bias, cerebral lateralization, cognition, left cradling bias (LCB)

1. Introduction

At the population-level, approximately 70% of mothers prefer to cradle their infants on the left side of their own bodies regardless of a number of factors including: activity type (e.g., calming, feeding, baby positioning: lateral, upright) (Bourne & Todd, 2004; Bundy, 1979; de Château, Holmberg, & Winberg, 1978; Donnot, 2007; Ginsburg, Fling, Hope, Musgrove, & Andrews, 1979; Hopkins, 2004; Matheson & Turnbull, 1998; Reissland, 2000; Reissland, Hopkins, Helms, & Williams, 2009; Salk, 1973; Sieratzki, Roy, & Woll, 2002; Sieratzki & Woll, 2002, 2004; Thompson & Smart, 1993; Todd & Banerjee, 2016; Tomaszycski, Cline, Griffin, Maestripieri, & Hopkins, 1997; Turnbull & Bryson, 2001; Turnbull & Lucas, 1991, 1996; Turnbull, Rhys-Jones, & Jackson, 2001; Vauclair & Donnot, 2005; Woll & Sieratzki, 2002), mother's handedness (Previc, 1991; Sieratzki & Woll, 1996, 2002; Vauclair & Donnot, 2005; but see van der Meer & Husby, 2006) or mother's culture (Bourne & Todd, 2004; Richards & Finger, 1975). The population-level *left side cradling bias* (LCB) tends to persist for at least the first 12 weeks of the baby's life (Todd & Banerjee, 2016).

1.1 Cerebral Lateralization

The causal nature of the LCB is debated, but the most parsimonious theory relies on cerebral lateralization of function. Cerebral lateralization is the dissociation of specialized processes of left and right hemispheres of the cerebral cortex (for a review see Rogers & Vallortigara, 2013). Because the nerve fibers of the motor cortices are contralaterally innervated, these dominant hemisphere processes can manifest as contralateral motor behaviors (Hellige, 1993). Although quite recently cerebral lateralization and associated contralateral motor biases was thought to be a human unique traits, non-human animal studies suggest that its origins date back to the rise of vertebrates (Rogers & Andrew, 2002; Vallortigara & Rogers, 2005) and possibly even earlier (Anfora et al., 2011; Bell & Niven, 2016; Frasnelli, Vallortigara, & Rogers, 2012). It is theorized that cerebral lateralization of brain function affords advantages to the organism. Strong cerebral lateralization may increase neural efficiency by allowing different functions to operate in parallel across hemispheres, decreasing duplication of functioning across hemispheres and eliminating the initiation of simultaneous and potentially incompatible behavioral responses (Rogers, 2002; Vallortigara, 2000).

Patterns of motor dominances in a wide range of animal species suggest that throughout evolution, the right hemisphere became dominant for urgent responses to the environment (e.g., predators) (e.g., Bonati, Csermely, & Sovrano, 2013; Franklin & Lima, 2001; Koboroff, Kaplan, & Rogers, 2008; Lippolis, Bisazza, Rogers, & Vallortigara, 2002; Martin, Lopez, Bonati, & Csermely, 2010; Rogers, 2000), while the left hemisphere emerged as dominant for routine and structured motor sequencing (e.g., feeding) (e.g., Alonso, 1998; Hopkins, 2007; Rutldige & Hunt, 2003; Westergaard & Suomi, 1996). Through human evolution, these hemispheric dominances (e.g., responding to novel and threatening stimuli) may have provided a platform for more sophisticated human cognitive capabilities (e.g., social emotional behaviors like infant cradling).

Research suggests that humans share a right hemisphere and left gaze bias for face perception (for a review see Demaree, Everhart, Youngstrom, & Harrison, 2005) (e.g., looking time of centrally presented faces) with sheep (Peirce, Leigh, & Kendrick, 2000), dogs and rhesus monkeys (Guo, Meints, Hall, Hall, & Mills, 2009) and chimpanzees (Morris & Hopkins, 1993). Additionally, the left side of the face in both humans and nonhuman primates has been reported to display emotive expression earlier and more intensely than the right side of the face, for example in chimpanzees (Fernandez-Carriba, Loeches, Morcilla, & Hopkins, 2002); macaques: (Hauser, 1993); marmosets: (Hook-Costigan & Rogers, 1998) and baboons (Wallez & Vauclair, 2011). These findings suggest that a human bias for both comprehending and producing facial expressions (identity and emotive expressions) dominated by the right hemisphere is an inherited primate trait. Although this manuscript focuses on the visual channel, human nonverbal, evolutionarily urgent vocalizations (e.g., cries and shouts) associated with threat or danger in the environment, elicit greater right-hemisphere activation compared with the left hemisphere (for a review, see Scott, Sauter, & McGettigan, 2009) suggesting that a right hemisphere dominance for social emotional processing in humans is not specific to a single sensory modality.

Cerebral lateralization of function interpreted through contralateral motor biases allows us to understand better how populations behave in the real world. For example, a left visual preference (right hemisphere) for detecting and monitoring conspecific behavior has ramifications for social positioning during natural human and non-human animal behavior. A study of chimpanzees and gorillas revealed that individuals navigate around conspecifics with a bias for keeping social partners to their left side (Quaresmini, Forrester, Spiezio, & Vallortigara, 2014). The study was later replicated with school children across a range of ages (Forrester, Crawley, & Palmer, 2014). The findings suggest that the right hemisphere may provide an advantage for monitoring the threat levels of conspecifics. However, human social emotional abilities go far beyond locomoting through social spaces. In human (and presumably many non-human animal species) the right hemisphere and left visual field play a critical role in discriminating between social companions and recognition of individuals based on familiarity (for a review, see Vallortigara & Versace, 2017).

1.2 Left Visual Field (LVF) Bias for Human Face Processing

Research suggests that a left visual field (LVF) bias for social stimuli is directly related to human population-level right hemisphere specialization for processing faces. Cognitive and behavioral studies consistently report LVF superiority for processing face stimuli, and these findings align with fMRI and ERP face processing responses, shown to be strongly associated with a LVF and right hemisphere superiority for face stimuli (for a review, see Yovel, 2016). Information presented to the LVF has a direct path to the right hemisphere of the brain and numerous brain imaging studies have reported an anatomically larger fusiform gyrus in the right hemisphere with heightened activation when processing faces compared with non-face stimuli (for a review, see Haxby & Gobbini, 2011). For example, a longitudinal study that implemented both brain imaging (fMRI) and behavioral (eye-tracking) methods demonstrated a positive association between an individual's LVF bias and the strength of right lateralized hemisphere activation during face processing (Yovel, Tambini & Brandman, 2008). The study also indicated that the level of hemispheric bias for face processing remained stable over time. Additional functional imaging research has demonstrated that the right hemisphere is not only dominant for processing faces in

general, but it is also selectively dominant for perceiving *human* face identity and strength of facial expressions (Gorno-Tempini & Price, 2001). Clinical studies also support a LVF and right hemisphere advantage for face processing. Individuals with right hemisphere damage demonstrated no LVF advantage and decreased ability to recognize faces (De Renzi, Perani, Carlesim, Silveri & Fazio, 1994). Furthermore, interference in face processing is found when the right (but not the left fusiform gyrus) is disrupted via intracranial electrodes (Jonas et al., 2015; Parvizi et al., 2012). Taken together, these studies converge to suggest that a population-level LVF bias for social stimuli reflects a right hemisphere specialization for attending to and processing social stimuli. As such, visual field biases for faces can act as behavioral markers of anatomical and functional cortical organization of domain specific social processing.

1.3 Social Laterality in Mother Baby Dyads

At no time would it seem more critical for animals to develop social bonds than during the rearing of offspring. Recent research has reported that a myriad of animal species possess social positioning biases, during mother-baby interactions, that favor the right hemisphere and the left eye (Giljov, Karenina, & Malashichev, 2018; Karenina, Giljov, Ingram, Rowntree, & Malashichev, 2017). This orientation of social positioning whilst nurturing offspring has also been identified in great apes (chimpanzees: Nishida, 1993; gorillas: Manning, Heaton, & Chamberlain, 1994). This behavior is likely to be akin to human cradling, supporting an evolutionary continuum of cerebral lateralization for processing social-emotional stimuli.

For the majority of the human population, the LCB facilitates a mutual (mother-baby) right hemisphere advantage for producing and perceiving social signals across visual and auditory social stimuli (Scola & Vauclair, 2010a; Sieratzki & Woll, 2002). The LCB creates a direct route to the right hemisphere through the left visual field of the mother, supporting rapid identification of facial identity and emotional state of the infant (Manning & Chamberlain, 1991). Consequently, the infant is provided with the more expressive left side of the mother's face (Vauclair & Donnot, 2005), which may have the potential to facilitate bonding and social development (Huggenberger, Suter, Reijnen, & Schächinger, 2009). Early social development research suggests that even

though neonates have underdeveloped sensory processing channels (Simion, Macchi Cassia, Turati, & Valenza, 2001) faces are still salient stimuli from birth (e.g., Farroni et al., 2005). Regardless of an underdeveloped visual system, neonates preferentially attend to patterns that contain the basic configuration of high-contrast areas of a face (e.g., Johnson, 2007). Moreover, neonates tested at birth demonstrate a preference for faces above other types of stimuli (Bower, 2001; Goren, Sarty, & Wu, 1975; Leppanen, Moulson, Vogel-Farley, & Nelson, 2007; Macchi Cassia, Valenza, Simion, & Leo, 2008; Simion et al., 2001; Umiltà, Simion, & Valenza, 1996; Valenza, Leo, Gava, & Simion, 2006). Johnson, Dziurawiec, Ellis, and Morton (1991) created a schematic illustration of the stimuli that might be optimal for eliciting a face-related preference in neonates. Consistent patterns of results were obtained across investigations of chicks (*Gallus gallus*) and human newborns. These two evolutionarily disparate species demonstrated similar behavioral biases toward face stimuli shortly after hatching or birth, supporting an evolutionary continuity in social orienting (Rosa Salva, Farroni, Vallortigara & Johnson, 2011).

Owing to the rate of cortical development, one might predict that newborns would not benefit from early exposure to visual social stimuli, however, brain imaging findings suggest that neonates may possess face sensitive subcortical neural regions (Johnson, Senju, & Tomalski, 2015; Umiltà et al., 1996), linked to an evolutionarily early predisposition to proto faces. New evidence suggests that basic visual face orienting abilities are in place prenatally as early as 30 weeks of gestations (Reid et al., 2017) and are not dissimilar to the filial responses demonstrated in chicks (Di Giorgio, Loveland, Mayer, Rosa-Salva, Versace, & Vallortigara, 2017). These early behavioral and neural attributes coupled with a reflexive rightward head-turning bias (in the final weeks of gestation through the first six months after birth; Güntürkün, 2003) and a mother's inclination to exhibit a LCB, create ideal conditions for both the infant's survival and developing a social brain.

1.4 Sex, Age and Experience

Evolutionary explanations set up an expectation that the LCB would appear early in ontogeny among both males and females and also without any prior experience of

holding infants (e.g. Saling & Bonert, 1983; Todd & Banerjee, 2016). Although the methods used to elicit cradling have been extremely varied across studies, the choice of experimental approach does not appear to influence the robust cradling LCB found in women. However, evidence of a LCB in men has been mixed (Bundy, 1979; Harris, Almerigi, & Kirsch, 2000; Harris, Spradlin, & Almerigi, 2006; Manning, 1991; Nakamichi & Takeda, 1995; Turnbull & Lucas, 1991). Some studies have reported that in men, the LCB is restricted to fathers (Bogren, 1984; Dagenbach, Harris, & Fitzgerald, 1988; Scola & Vauclair, 2010b) and men whose professions required infant care (de Château, 1983). These findings suggests that gender could be an influential LCB factor and additionally that there might be a developmental or experiential component to the LCB. However, to date, it is unclear if any gender bias is mediated by experience or innate predisposition, nor do we understand what exactly it is that makes the LCB emerge in both men and women.

Evidence from cradling studies of girls and boys suggest that a propensity to cradle left is present and visible in children. Girls and boys (aged 2-16 years) demonstrated an LCB using a doll (Pileggi, Malcolm-Smith, & Solms, 2015; Souza-Godeli, 1996; but see de Château & Andersson, 1976). However, Manning and Chamberlain (1991) found that the proportion of left cradling increased with age in girls, only becoming biased to the left by six years of age. In contrast to the findings associated with men suggesting that experience of babies is required to elicit a LCB, boys demonstrated a later developmental trajectory, with a LCB becoming visible not before 16 years of age (de Château & Andersson, 1976).

Across cultures, gender-specific socialisation and family experience might impact the presence of the LCB in young male and female children. In western countries, girls are preferentially socialized to interact with dolls (considered a female-stereotyped toy) from a young age “and may gain formative experience through these interactions” (Todd & Banerjee, 2016). Culturally, boys may be discouraged from interacting with female-stereotyped toys and therefore gain less experience than their female counterparts for developing a cradling bias (Todd, Barry, & Thommessen, 2017). Additionally, experience of sibling care, (as measured by birth order), may also provide

important experiences triggering or influencing the strength or propensity for a cradling bias in children. To date, the implementation of non-gender-stereotyped cradling stimuli and the influence of sibling experience have yet to be addressed in systematic fashion to explore how they might contribute to a population-level LCB.

1.5 Motor Biases as a Marker of Cognitive Ability

Motor biases act not only as markers of brain organization, but have also been shown to correlate significantly with subsequent cognitive outcomes (Toga & Thompson, 2003). For instance, at the population-level, strong right hand dominance in children corresponds with the typical development of fine motor skills and subsequent attainment of typical language abilities (left hemisphere dominant; Leask & Crow, 2001). Conversely, weak hand dominance (ambidexterity) is associated with the development of poorer fine motor abilities and weaker language ability (compared with strongly handed individuals) in addition to a rise in neurodevelopmental and mental health disorders (e.g., Rodriguez et al., 2010).

There is currently no evidence suggesting an association between the side of the mother's body on which babies were cradled during the early weeks of infancy and the level of subsequent socio-communicative development. Moreover, population patterns do not necessarily translate to the individual because at the individual level, we cannot be certain of brain organization based on motor biases. However, one retrospective study of healthy adults revealed that individuals who were held with a LCB (derived from family photos) developed a typical left visual field (right hemisphere) bias for responding to chimeric faces, whereas adults that were cradled with a right-arm bias did not (Vervloed, Hendricks, & van den Eijnde, 2011). While all participants could effectively identify the identity and emotional expression of face stimuli, those individuals who were cradled on the left were significantly faster at doing so. The findings suggest that there is significant 'typical' variation in the population and that babies cradled on the left may develop an enhanced right hemisphere bias for processing social emotional stimuli. In fact, one study has even suggested that faces of right-cradlers were less visible from the "infant viewpoint" compared to those of left-cradlers (Hendriks, van Rijswijk, & Omtzigt, 2011). However,

at this time it is impossible to reconcile if right side cradled babies were predisposed through heritability (for a genetic account of cradling, see Manning & Denman, 1994) to decreased cerebral lateralization or if the cradling side influenced development.

Although visual and motor biases for social positioning of mother-baby dyads during cradling appear to be rooted in an evolutionarily old right hemisphere advantages for processing social-emotional stimuli, we do not yet understand what features of the baby elicits the LCB in the mother; or if gender, age or experience are contributing factors. Additionally, we seek to better understand better the link between motor biases, cerebral lateralization of function and association with cognitive developmental ability (e.g., Forrester, Pegler, Thomas, & Mareschal, 2014; Lindell & Hudry, 2013).

In the current study, we employed a range of manual motor tasks that explored: hand dominance, cognitive control (impulsivity) and cradling behavior in young typically developing young children. This research takes steps towards addressing some of the gaps in the literature regarding the LCB, motor biases in general and their relationship with cognition. With respect to the cradling results, we predicted: 1) children will demonstrate a preference to hold a doll representing a human infant on their left side, 2) gender, age and experience may influence cradling side bias of the infant human doll; 3) children will demonstrate a preference to hold a non-gender-stereotyped doll (infant primate doll) on their left side because the introduction of the infant primate doll will eradicate socially induced effects of gender, age or experience; 4) no cradling side bias will be found when children hold a control object of the same weight and dimensions as the doll(s) but without social features; 5) the addition of rudimentary facial features to the control object will be sufficient to elicit a left cradling bias in children. With respect to the relationship between motor biases and cognitive ability scores, we predicted: 1) there will be a difference in social ability scores based on cradling side bias and 2) there will be a relationship between the strength of hand dominance for manual motor tasks and communication ability scores.

2. Material and Methods

2.1 Participants

Ninety-eight typically developing children (54 girls, 44 boys) attending reception or year 1 participated in this study (mean age = 69.95 months, SD = 10.64). All children attended a mainstream primary school in central London. Children at this developmental age were chosen because both handedness (e.g., Gudmundsson, 1993) and the cerebral processes associated with hand preference (Bates, O'Connell, Vaid, Sledge, & Oakes, 1986; Fagard & Marks, 2000) have stabilized by then, while also minimizing the amount of time that children have been exposed to socially defined lateralized behaviors. This is also the age used by similar work in this area (e.g., Forrester, Pegler, Thomas, & Mareschal, 2014). For each child, the number of younger siblings living in the home was recorded in order to assess the extent to which exposure to a younger sibling may impact cradling bias. Please see Table1.

Table 1. Demographic information of participants

Participant	N	Mean Age in Months	Standard Error	Age Range in Months	Self Report Handedness	Younger Sibling
Girls	54	69.44	1.52	34	7 (L), 47 (R)	17
Boys	44	67.05	1.70	34	8 (L), 36 (R)	9

2.2 Testing Conditions

Children were tested in a small (approximately 2 x 4 metres) quiet room with plain walls. Participants alternated between two testing stations at opposite ends of the room. Each testing station was operated by a different researcher. Each child was presented with three manual-based motor tasks, interspersed with three cradling trials. The tasks were counterbalanced to avoid order effects. Participants began testing at the manual motor station. When the child was at one testing station, the researcher at the other testing station was responsible for coding behavior. The objectivity of coding was high due to the categorical coding of tasks and cradling trials (left, right, correct, incorrect). Inter-rater reliability was performed for 10% of participants, resulting in 100% reliability ($r = 1.0$).

The number of participants varied across tasks (see section 2.4.1). All children participated in the *Knock and Tap*, *Peg Board* and *Card-Lacing* tasks however three children's data from the survey tasks were not completed by key teachers. For cradling trials, only those trials where children followed task instructions and held stimuli in an upright or lateral position were included in analyses. Lower participant numbers for proto-face and no-face pillow stimuli were the result of a between-participant contrast, compared with within-participant contrast for other cradling stimuli (see section 2.4.1). Please see Table 2.

Table 2 Sample characteristics as a function of task.

Tasks	N	N by Sex	Mean Age (months)	Hand Classification	Younger Siblings
Knock and Tap	98	Girls (54) Boys (44)	69.44 70.40	7 (L), 47 (R) 8 (L), 36 (R)	17 9
Peg Board	98	Girls (54) Boys (44)	69.44 70.40	7 (L), 47 (R) 8 (L), 36 (R)	17 9
Card Lacing	98	Girls (54) Boys (44)	69.44 70.40	7 (L), 47 (R) 8 (L), 36 (R)	17 9
Social Survey Items	95	Girls (53) Boys (42)	69.32 70.74	7 (L), 46 (R) 8 (L), 34 (R)	17 9
Communication Survey Items	95	Girls (53) Boys (42)	69.32 70.74	7 (L), 46 (R) 8 (L), 34 (R)	17 9
Cradling Trials	N	N by Sex	Mean Age (months)	Hand Classification	Younger Siblings
Infant Human Doll	80	Girls (49) Boys (31)	69.96 71.68	6 (L), 43 (R) 6 (L), 25 (R)	17 8
Infant Primate Doll	74	Girls (42) Boys (32)	68.95 70.74	6 (L), 36 (R) 6 (L), 26 (R)	13 7
Proto-Face Pillow	37	Girls (21) Boys (16)	74.91 70.69	3 (L), 18 (R) 3 (L), 13 (R)	7 4
No-Face Pillow	44	Girls (25) Boys (19)	66.32 70.26	4 (L), 21 (R) 3 (L), 16 (R)	7 5

2.3 Manual Motor Tasks

2.3.1 Knock and Tap task:

Each participant began with the *Knock and Tap* task was taken from the NEPSY neuropsychological test battery (Kemp, Kirk, & Korkman, 2001; Korkman, Kirk, & Kemp, 2000). The *Knock and Tap* task was introduced to assess attention and effortful control in young children, as it requires the inhibition of a prepotent action. In this

task, the experimenter sat opposite the child (across a table) with hands laid flat on the table. The child was asked to mirror their hand position. Next, the child was asked to indicate their 'favorite hand for writing'. This was taken as indicative of the dominant hand for fine motor activities. There was a 96% concurrence between the child's chosen hand and the hand classification based on the subsequent motor tasks described. The researcher told the child that they would play the game with the indicated (dominant) hand and the other hand (non-dominant) would remain still on the table. The experimenter always conducted the task with the hand that mirrored the child's dominant hand. The researcher provided participants with the following instructions and an accompanying demonstration: "When I knock on the table (closed fist makes contact with the table with an audible sound), you tap on the table (opened palm makes contact with the table with an audible sound). And, if I tap on the table, you knock." Two practice trials were given to make sure that the child understood the task instructions. Fifteen test trials followed as specified in the NEPSY manual (Knock-Knock-Tap-Knock-Knock-Tap-Tap-Knock-Tap-Tap-Knock-Tap-Tap-Knock). Hesitations were scored as breaks in the flow of the rhythmic trials, and incorrect responses were also recorded.

We used two different manual motor tasks (*Pegboard* and *Card-lacing*, see Figure 1) to assess actual hand dominance. Unimanual actions are typically used to assess hand dominance for fine motor control, thus we introduced the *Pegboard* task. However, unimanual actions (actions that require a single hand to perform an action) are often simple enough that participants may perform the task efficiently with either hand, increasing the likelihood of ambi-preferent scores. Evidence from the laterality literature suggests that bimanual actions (actions that require the use of both hands, such that one hand is holding an object whilst the other hand performs manipulations of the object) demonstrates greater sensitivity as a measure of hand dominance (for a review of hand dominance measures, see Forrester, 2017) Thus, we also introduced the *Card-lacing* task.

2.3.2 Pegboard task:

Participants sat across a table directly opposite the researcher. The researcher produced a white 10 x 10 holed plastic pegboard (*Invicta*® pegboard: 17 x 17 cm, 739 grams). The pegboard and a bowl of multicolored plastic pegs (red, blue, green, yellow) were placed at the child's midline with the pegboard in front of the child and bowl of pegs behind the pegboard from the child's perspective, affixed to the table using Blu Tack®. The pegboard possessed a red outline of a square drawn on the board measuring 6 x 6 holes.

The children were asked to select only red pegs and complete the outline of the 6 x 6 red square. This task required the placement of 20 red pegs. Participants were asked to work as quickly and as accurately as possible. Participants were given a maximum of ninety seconds to complete the task. The researcher scored the number of left handed and right handed peg placements. Errors in the form of: 1) failed attempts to place a peg in a hole and 2) the use of the wrong-colored pegs were recorded. A laterality index scores (LIS) was calculated for each participant using data from the pegboard task. LIS were calculated using the formula $[LI = (R - L)/(R+L)]$, with R and L corresponding to the frequency of events resulting in scores ranging between -1.0 and +1.0 where greater positive values reflect an increasing right hand preference and greater negative values represent an increasing left hand preference.

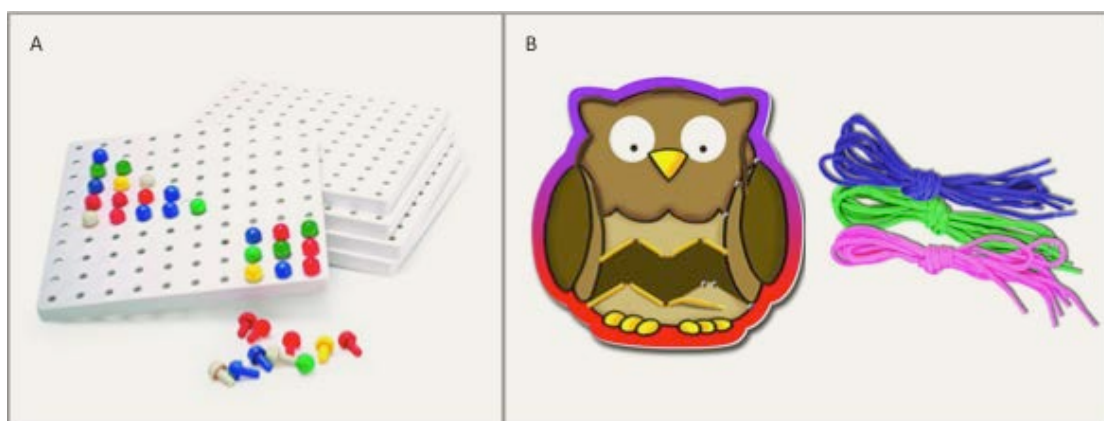


Figure 1. Task stimuli for (A) the Pegboard and (B) Card-lacing tasks.

2.3.3 Card lacing task stimuli

This task was used to assess bimanual coordinated hand dominance. Participants sat at a table, across from the researcher. The researcher provided the child with a lacing card and a jumbo lace with a bound end (*Early Learning Centre® My First Lacing Pictures*). To control for the number and position of holes across participants the same lacing card was used for all participants. Children were instructed to weave the lace through all of the holes in the card. The researcher first provided a demonstration with their own lacing card and did not begin the task until the child had successfully threaded two practice holes. The children were then given ninety seconds to complete as much of the card as possible in no particular order. The number of holes completed and the number of errors (failed attempts to place the head of the lace through a hole) were recorded. LIS scores were also calculated for the card-lacing task.

2.4 Cradling Task

Cradling trials were conducted to assess if children demonstrated a preference for holding different types of social stimuli and a control item with a bias to one side of their body. Cradling stimuli consisted of: an infant human doll, an infant primate (orang-utan) doll, a proto-face pillow and a no-face pillow (Figure 2). All cradling stimuli were altered using fishing weights such that the head portion weighed 2 lbs. and the posterior weighed 1.5 lbs. and the total weight was 5 lbs. All cradling stimuli were 22 inches in length except for the infant human doll, which was 18 inches in length. Doll stimuli wore newborn-sized nappies under unisex, cream-colored one-piece playsuit with a marl-grey pattern. A zip fastening was concealed on the back. The proto-face and no-face pillows were wider at the top than at the bottom and covered with the identical one-piece playsuit fabric and back zip fastening. These stimuli were stuffed with a contained bag of plastic beads positioned in the posterior region to match the posterior region of the dolls. The beads were wrapped in fleece fabric and padded out with polyester cushion filling. The only difference between the proto-face and no-face pillow stimuli was that the proto-face pillow was embellished with a basic configuration of a face, equal to the mean size of the doll stimuli and consistent with the proportions identified by Johnson and collaborators (1991).



Figure 2. Illustrations of (A) the infant human doll, (B) infant primate doll, (C) proto-face pillow and (D) no-face pillow.

2.4.1 Procedure and Behavioral Coding

The cradling task comprised of three trials. Participants began with one of either the proto-face pillow or the no-face pillow. The pillow trial was always presented as the initial cradling trial so that the cradling trials involving the infant human and primate dolls did not ‘contaminate’ these stimuli with a notion of ‘animacy’ or ‘dollness’. Each participant engaged in only one of these conditions because counterbalancing the stimuli would have resulted in some children cradling the proto-face pillow before the no-face pillow. In these cases there was concern that the proto-face pillow would contaminate the subsequent no-face pillow with a quality of ‘animacy’. All participants were then presented with both the infant human and primate dolls in a counterbalanced fashion. The type of pillow used (face vs. no face) was therefore a between-participant contrast, whereas the type of stimulus (pillow, human infant doll or primate infant doll) was a within-participant contrast.

Each cradling trial was conducted with identical procedures to assess whether children would demonstrate a left or right side cradling (see Figure 3). To begin a cradling trial, the child was asked to stand up from the manual motor station, walk to the back of the room and sit in a chair located equidistant from the walls on either side. The researcher then approached the child centrally and said: “I’m going to give you something to hold. Can you take it and hold it like this?” A symmetrical cradling gesture without holding anything was then made (Pileggi et al., 2015; and see panel B, Figure 4). Next, the researcher walked back to the manual motor station with their

back to the participant to retrieve the cradling stimulus from a concealed bag under the testing station. The stimulus was held centrally and upright against the researcher's chest so as not to be visible to the participant until the researcher turned back to walk towards the child. The researcher approached the child and extended the stimulus to the child in an upright position towards the child's midline.

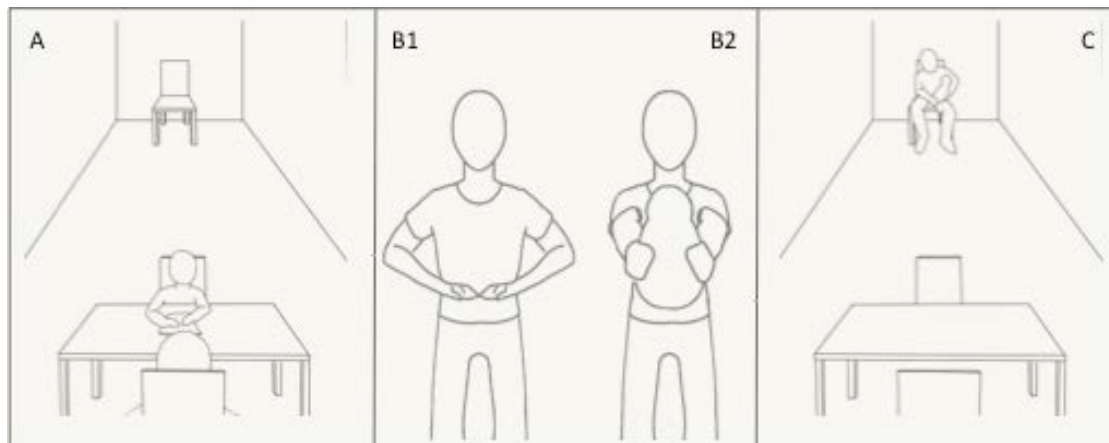


Figure 3. Schema of the testing room layout with the manual motor testing station in the foreground and the cradling station (chair) in the background. Panel A illustrates the child facing the researcher engaged in a task at the manual motor station. Panel B1 illustrates the researcher providing the cradling gesture to the child in advance of producing the cradling stimuli. B2 demonstrates the researcher presenting the cradling stimulus upright and midline to the participant and panel C depicts a successful cradling trial whereby the child cradles a doll in a side-biased lateral or upright position.

If the child did not hold the stimulus in one of the desired positions (lateral or upright), the researcher re-iterated the cradling gesture. When a stimulus had been cradled for approximately 30 seconds, the cradling side was recorded. If the child held the doll in any other position (face down, above the head, on the floor) or rejected the stimulus, the trial was excluded from the analyses below.

2.5 Socio-communication Survey

The key teacher for each child was asked to complete a 14-item socio-communicative survey. The survey was developed specifically for this investigation to provide a basic

social ability score (items 2, 3, 5, 7, 9, 11, 13) and a basic communication ability score (items 1, 4, 6, 8, 10, 12, 14) for five year-old children (see Table 4). The survey was scored by the key teacher of each participant using a Likert scale for the categorical descriptions: 'strongly disagree', 'disagree', 'neutral', 'agree' and 'strongly agree'. Categorical selections were transcribed into scores of 1-5 where high scores equated to stronger ability levels. Communication items were developed to reflect speech, language and communication milestones for five year olds. Information about milestones were derived from *Talking Point*, a website about children's speech, language and communication. *Talking Point* is run by I CAN, and receives funding from The Communication Trust. The Communication Trust is a coalition of over 50 not-for-profit organization that support people who work with children in England to support their speech, language and communication needs (SLCN). Social items were developed to reflect social milestones for five year olds. Information about milestones were derived from the United States Center for Disease Control and Prevention's Milestone Tracker: 'Your Child at 5 Years' Social/Emotional checklist.

All descriptive and statistical analyses were conducted using SPSS (Version 24). Alpha was set at 0.05 and all tests were two-tailed.

3. Results

Although 98 children participated in the study, not all children completed all tasks. Table 2 (below) illustrates the number of participants that completed each task, the mean scores for: the manual motor tasks (*Pegboard* and *Card-lacing*), the task for effortful control/impulsivity (*Knock and Tap*) and the frequency of left and right cradling trials for the *Cradling Task* trials (infant human doll, infant primate doll, proto-face pillow, no-face pillow).

Table 2 Group mean scores for each of the 10 study measures.

Manual Motor and Socio-Communicative Tasks	N	Maximum Score	Mean Score	SE
Knock and Tap: Number of Errors	98	15	2.01	.286
Knock and Tap: Number of Hesitations	98	15	1.20	.142

Peg Board: Laterality Index Score	98	-1/+1	.504	.051
Card Lacing Laterality Index Score	98	-1/+1	.476	.054
Social Ability Survey Scores	95	5	4.27	.048
Communication Ability Survey Scores	95	5	4.29	.059
Cradling Trials	N	Trials per Child	Left	Right
Infant Human Doll	80	1	52	28
Infant Primate Doll	74	1	25	49
Proto-Face Pillow	37	1	27	10
No-Face Pillow	44	1	19	25

3.1 Cradling Task

Cradling results are reported in Table 3 and Figure 4. We begin by considering the effects of Gender then turn to considering the impact of motor and stimulus variables on cradling behaviors. Binomial tests were conducted to determine significant cradling side biases.

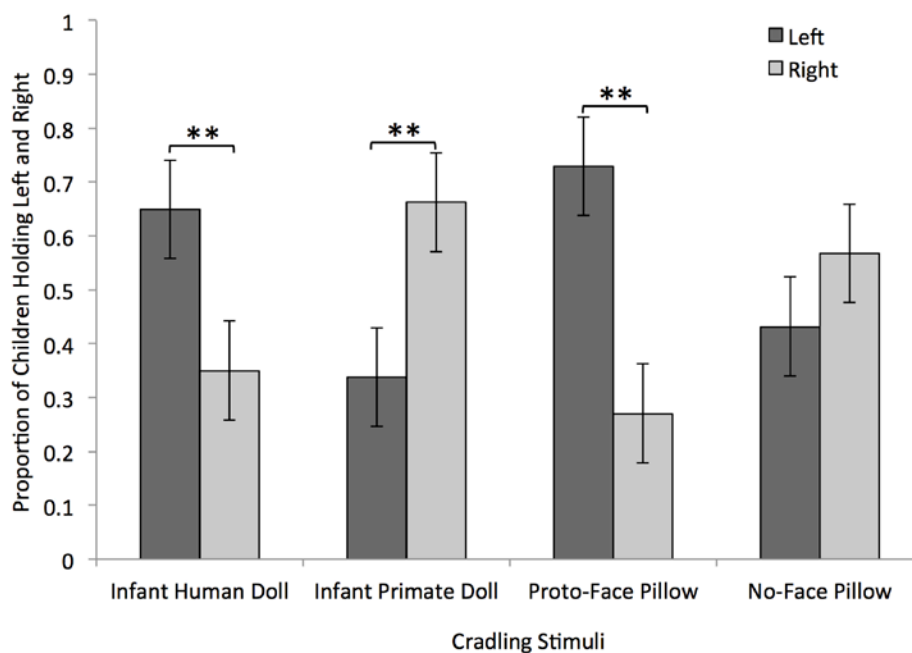


Figure 4. Over all proportion of cradling side for each stimulus type.

3.1.1 Infant Human Doll

Children held the human infant doll significantly more often in a left cradling position than a right cradling position ($P < .01$). Although there were no significant differences

between boys' and girls' cradling behaviors, only Girls showed a significant LCB ($P < .05$) with the reduced Ns that occur when splitting the sample into two independent groups.

3.1.2 Infant Primate Doll

Children held the infant primate doll significantly more often in a right than in a left cradling position ($P < .01$). However, boys were significantly more likely than girls to hold the infant primate doll in a right side cradling position ($P < .05$). Moreover, only boys demonstrated a significant right-sided cradling bias ($P < .01$) with the reduced participant numbers that occurred when splitting the sample into two independent groups.

3.1.3 Proto Face Pillow

Children held the proto-face pillow significantly more often in a left cradling position than a right cradling position ($P < .01$). There were no significant differences between Boys' and Girls' cradling behaviors however, only girls demonstrated a significant LCB ($P < .05$) with the reduced participant numbers that occur when splitting the sample into two independent groups.

3.1.4 No Face Pillow

Neither girls nor boys held the no-face pillow with a significant side bias. Additionally, girls and boys did not differ significantly in their cradling behavior of this stimulus.

No effects of trial order were identified with respect to the condition sequence in which holding stimuli were presented to participants.

Table 3 Frequencies, laterality indices and two-tailed p-values of sign-tests for holding side across cradling conditions broken down by gender.

Condition	Infant Human Doll	Infant Primate Doll	Proto Face Pillow	No Face Pillow
Girls Left	33	18	16	12
Girls Right	16	24	5	13

Laterality Index	-.347	.143	-.524	.040
P-Value	0.0213*	NS	0.0266*	NS
Boys Left	19	7	11	7
Boys Right	12	25	5	12
Laterality Index	-.226	.563	-.375	.263
P-Value	NS	.0021*	NS	NS
Group Left	52	25	27	19
Group Right	28	49	10	25
Laterality Index	-.300	.324	-.460	.136
P-Value	.0097**	.0071**	0.0076**	NS

574

575 A chi-squared test of association indicated a significant interaction between holding
576 sides for the infant human and primate dolls, $\chi^2 (1, N = 67) = 8.735, p = .004$. Children
577 who held the infant human doll on the left were equally likely to hold the infant
578 primate doll on the left ($n = 21$) or right side of their bodies ($n = 20$). However,
579 children who held the infant human doll on the right were significantly more likely to
580 hold the infant primate doll on the right side ($n = 22$) compared to the left side ($n =$
581 4) of their body.

582

583 3.2 Sex, Age and Experience

584 Statistical analyses indicated that neither school year nor mean age in months
585 interacted with holding side of the human doll for girls. However, a Mann-Whitney U
586 test showed that boys who held the infant human doll on the left side of their bodies
587 (Mean = 68.21, SE = 2.42) were significantly younger than boys who held the infant
588 human doll on the right side of their bodies (Mean = 77.17, SE = 2.30) ($U = 56, p =$
589 .018). A similar pattern was identified for Boys holding the infant primate doll. Boys
590 who held the infant primate doll on their left side (Mean = 63.57, SE = 3.48) were
591 significantly younger than Boys who held the primate doll on their right side (Mean =
592 72.83, SE = 2.04) ($U = 56, p = .040$). A Chi-squared test of association, however
593 indicated that boys' holding side and school year were not significant for either the
594 infant human or primate dolls, suggesting that age in months is a more sensitive
595 measure of experience than school year.

596

597 Chi-squared tests of association revealed no significant interactions between the
598 holding side of any of the cradling stimuli (infant human doll, infant primate doll,

proto-face pillow, no-face pillow) and experience (with or without younger sibling/s). Thus, sibling experience did not appear to moderate cradling behavior in this sample of children.

3.3 Cradling side and Hand Dominance

Cradling side for any of the four kinds of test stimuli was not associated with hand dominance (as measured in the *Knock and Tap* task, nor was it associated with laterality indices (LIS) derived from the *Pegboard task*. A Mann-Whitney *U* test indicated that laterality indices derived from the *Card-lacing* task did associate with cradling bias for the primate doll whereby children who held the infant primate doll on the left were significantly more right-handed (Mean = .689, SE = .074) than children who held the infant primate doll on the right (Mean = .351, SE = .081) ($U=391$, $p=.01$). LIS did not associate with cradling bias for any of the other cradling stimuli.). There were no sex differences across the hand dominance scores.

3.4 Cradling Biases and Socio-communicative Scores

A Pearson test of correlation indicated that mean scores for the social and communicative survey items were highly correlated with each other, $r(95) = .645$, $p < .001$. Additionally, a Pearson test of correlation indicated that social ability scores were positively correlated with the frequency of correct trials from the *Knock and Tap* task $r(95) = .293$, $p = .004$. Communicative ability scores were marginally associated with the number of correct trials in the *Knock and Tap* task $r(95) = .186$, $p < .07$. *Knock and Tap* and communicative ability survey scores did not significantly differ between left and right infant human doll cradlers. However, a Mann-Whitney *U* test indicated that children who held the infant human doll with a LCB ($n=51$) had a significantly higher social ability score (Mean = 4.31, SE.073), compared with those that held the infant human doll on the right ($n = 28$) (Mean = 4.14, SE.070) ($U=497$, $p = .025$). Finally, infant primate doll, proto-face pillow and no-face pillow stimuli cradling side did not associate with *Knock and Tap* task, social survey or communication survey scores. There were no sex differences across the socio-communicative scores. Please see Table 4.

Table 4 Social and communication survey items, mean scores, and standard deviations (SD) as a function of cradling the infant human doll on the left and right side.

Item	Statement	Side	N	Mean	SD
1	Can talk about things that have already happened or will happen in the future with a good understanding of time, for example 'yesterday we went to visit a museum'	Left Right	51 28	4.55 4.36	0.61 0.73
2	Wants to please their teacher	Left Right	51 28	4.43 4.18	0.67 0.55
3	Is likely to follow rules	Left Right	51 28	4.29 4.00	0.73 0.82
4	Can use long and detailed sentences for example " We went to the park, but we came home because Mary hurt herself"	Left Right	51 28	4.41 4.25	0.75 0.89
5	Will share with others on their own accord	Left Right	50 28	4.28 4.18	0.67 0.67
6	Can communicate easily with familiar adults and with other children	Left Right	51 28	4.45 4.25	0.70 0.89
7	Can tell the difference between real and imaginary/pretend	Left Right	51 28	4.47 4.25	0.58 0.65
8	Can speak of imaginary conditions and says things like "I hope...."	Left Right	51 28	4.24 4.07	0.71 0.81
9	Likes to sing, dance and act	Left Right	51 27	3.94 3.70	0.76 0.54
10	Can take turns in longer conversations and stay on the same topic	Left Right	51 28	4.37 4.14	0.66 0.89
11	Prefers to play interactively with others (cooperative play), rather than playing alone (solitary play) or next to others but without interaction (parallel play)	Left Right	51 28	4.41 4.36	0.61 0.62
12	Engages in pretend play (e.g., role-playing alone or with others and/or using one object to represent another – for example: "This block is a telephone".)	Left Right	51 28	4.25 4.07	0.56 0.60
13	Engages in eye contact when speaking to others	Left Right	51 28	4.55 4.43	0.61 0.57
14	Describes objects and events with lots of detail	Left Right	50 28	4.26 4.14	0.85 0.93

Note: Shaded rows denote social items and non-shaded rows denote communication items.

4. Discussion

4.1 Cradling Behavior

Despite the fact that the present results reflect children from an isolated school and could represent a micro-culture specific to this school, the children who participated in this study attended a Central London primary school, which drew from a diverse multicultural catchment area. Moreover, the findings are consistent with previous research across a range of schools and ages (see Jones, 2017). Findings from the present study demonstrated a population-level LCB, supporting an early evolutionary propensity for population-level left visual field and right hemisphere dominance for

social-emotional processing (Bourne & Todd, 2004). The presence of an early and visible LCB in children was further supported by results from the proto-face and no-face pillows. The proto-face pillow elicited a population-level LCB while the no-face pillow (control stimulus) did not. The current findings suggest that the salience of the most rudimentary face configuration (e.g., Johnson et al., 1991) is sufficient to elicit a LCB in children. This finding prompts the need for further infant research, to understand the role of cerebral lateralization during typical development. Neonates, from birth, demonstrate a preference for faces above other types of visual stimuli (Bower, 2001; Goren, Sarty, & Wu, 1975; Leppanen et al., 2007; Macchi Cassia et al., 2008; Simion et al., 2001; Umiltà et al., 1996; Valenza et al., 2006), yet no studies have yet to establish if a visual field bias for social stimuli exists early in development.

In direct contrast to our hypothesis, children held the infant primate doll significantly more often in a right versus left cradling position. One possible interpretation of this finding comes from adult cradling studies, which have reported an association between affective symptoms and the strength of the LCB. For example, mothers who held their infants on the right side reported higher stress levels than those holding on the left (Reissland et al., 2009; Vauclair & Scola, 2009). The immediate effect of stress is also associated with right-holding; women who undertook a bilateral cold pressor task, which significantly increased their blood pressure and heart rate, were more likely to hold a doll on the right than controls (Suter, Huggenberger, & Schächinger, 2007). Therefore a decline in, or reversal of, the typical LCB is evidenced in adults undergoing stress, possibly, as Harris (2010) discusses, because positioning the stimulus in the right visual field/left hemisphere of the holder may reflect an “inaction-withdrawal” response rather than approach and engagement.

Cradling the unfamiliar primate doll might have aroused mild anxiety in our participants. Indeed, some boys and girls indicated that they had found the primate doll “scary”. Several children were reluctant or even refused to pick it up, a response not found in the ‘baby doll’ or ‘pillow’ conditions. Whilst we did not envisage that the commercially available primate doll would appear frightening, it was perhaps unexpected in the experimental situation and therefore increased children’s anxiety.

Consequently, stress may have been responsible for the increased rates of right side cradling in this condition.

There are other alternative interpretations. It is possible that a LCB is present only for those social stimuli that represent infancy. Todd and Banjeree (2015) reported that the LCB was robust for new mothers the first 12 weeks of their child's development. However, evidence of a LCB became greatly reduced or disappeared after approximately three months. Babies are born with underdeveloped sensory and motor systems and their survival is reliant on the mother's perception of their wellbeing. It is possible that children perceived the infant human doll as less than 12 week-old, but perceived the infant primate doll as older than 12 weeks of age. Alternatively, it is possible that the LCB is triggered by species-specific stimuli. A right hemisphere dominance, manifesting as a LVF advantage for social stimuli, may be a response to well-familiarized stimuli. The 'expertise hypothesis' suggests that right biased fusiform gyrus activity is positively correlated with the level of speciality of the individual and can be elicited by face and non-face stimuli (Gauthier, Skudlarski, Gore, & Anderson, 2000). Thus, it is possible that since human faces are more familiar than non-human primate faces, the less familiar infant primate doll did not elicit the LCB in children. However, with this interpretation, it should be taken into consideration that the non-conspecific and unfamiliar proto-face pillow *did* elicit a LCB in children rather than a decrease or reversal in LCB.

We found an interaction between cradling sides for the infant human and primate dolls. Children who held the infant human doll on the left were equally likely to hold the infant primate doll on the left or the right. However, children who held the infant human doll on the right were also more likely to hold the infant primate doll on the right. These findings illustrate that child behavior was sensitive to the nature of the cradling stimuli. Furthermore, this pattern of results illustrates the possibility that robust but disparate behavioral phenotypes can emerge in a population of typically developing children.

4.2 Sex, Age and Experience

Holding side for any of the cradling stimuli was not associated with age or experience of having a younger sibling, however sex difference were revealed. Boys demonstrated a weaker LCB than girls for both the infant human doll and the proto face pillow. Although boys held these stimuli proportionately with a left side bias, the results for boys as an independent group were not significant. One interpretation is that these findings represent a question of power and that larger sample sizes may reveal a significant, yet reduced LCB in boys compared with girls. A weaker LCB in boys may be the result from a variety of circumstances including differences in sex, developmental rate and experience. Todd and Banerjee (2016) suggested an effect of gender-stereotyped infant human doll, whereby boys may be less inclined to interact with a baby doll. De Château and Andersson (1976) suggested that girls and boys might have different developmental trajectories such that boys develop an LCB later than girls. Because evidence of a LCB in men has been reported in studies of fathers (Bogren, 1984; Dagenbach et al., 1988; Scola & Vauclair, 2010b) and men whose professions required infant care (de Château, 1983), experience may play a critical role in triggering the LCB. However, in the present study, boys, demonstrated an effect of age that was contrary to the prediction that the occurrence of the LCB would increase with increasing age, as a result of increased experience. Boys, but not girls, demonstrated a significant age difference for left and right side holding of both the infant human doll and the infant primate doll. Boys who held the infant human doll on the left were significantly younger than those who held it on the right. The same was true for boys holding the infant primate doll. The decrease in the LCB with age may reflect boys' increasing disinclination to play with female-gender-typed toys. A meta-analysis conducted by Todd and colleagues (2018) demonstrated that older boys played more with male-gender-stereotyped toys than with female-gender-stereotyped toys compared with younger boys. Future studies should consider longitudinal approaches to disentangle confounds of age, experience and perhaps cultural features (e.g. school, family) that may contribute to holding biases in young boys.

A significant interaction between sex and cradling side for the infant primate doll revealed that boys, but not girls held the infant primate doll with a significant right

side cradling bias. In this study the inclusion of a doll representing an infant primate doll was presented as a control stimulus for the possible reluctance of boys to breach gender norms by engaging with a typical 'baby' doll (Todd & Banerjee, 2016). The interpretation of a right side bias for holding the infant primate doll is discussed above, however, the reason why girls revealed a significantly weaker right side bias compared with boys is unclear. The weaker right side cradling bias in girls for the infant primate doll may again result represent a question of power. Larger sample sizes may reveal a significant right side cradling bias in girls, but why it would be weaker than in boys remains to be explored. Further investigations are required to better understand if and when development and experience impacts the strength of a population-level LCB in males and females.

4.3 Cradling Behavior and Hand Dominance

Overall, hand classification (self report) and strength (as derived by the *Pegboard* and *Cared-lacing* tasks) were not associated with cradling side of the human infant doll proto-face and no-face pillows. These finding are consistent with previous research demonstrating that neither self-report of hand classification, nor strength of hand dominance (LIS scores) are associated with population-level LCB (Previc, 1991; Sieratzki & Woll, 1996, 2002; Vauclair & Donnot, 2005). Children who were not right handed were equally likely as their right-handed counterparts to hold the infant human doll on the left. Studies of hand dominance report that approximately 70% of left-handed adults and children alike have dominant language processes in the left hemisphere (e.g., Knecht et al., 2000; Szaflarski et al., 2013). These individuals, like 95% of right-handers will possess right hemispheres that are dominant for producing and perceiving social-emotional stimuli. Therefore, the majority of right-handed and left-handed individuals will express a dominant left visual field preference for viewing social stimuli that is influenced by the dominant right hemisphere for processing social-emotional stimuli.

Infant primate cradling side did not interact with hand classification, but did elicit significantly different strength laterality index scores (LIS) for only the *Card-lacing* task. Children who held the infant primate doll with a right cradling bias were

significantly more right-handed than children who held the infant primate doll with a LCB. As an example of a bimanual coordination task, the *Card-lacing* task may be revealing the more sensitive measure of hand dominance in children compared with the LIS derived from the *Pegboard task* (e.g., unimanual task) (Fagard & Marks, 2000). One interpretation is that children perceived the infant primate doll as 'less animate' and more of an object. It is possible that the infant primate doll was considered an inanimate object to be held and/or manipulated by the dominant hand. In support of this interpretation, the no-face pillow was also held with a right side bias, although not significantly more than chance in the current sample.

4.4 Cradling Behavior and Socio-Communicative Ability

Holding side for any of the cradling stimuli was not associated with communication survey scores or inhibition scores. In contrast, social ability scores were positively correlated with inhibition scores, such that as social ability scores increased, so did the number of correct trials for the *Knock and Tap* task. This finding suggests that children with higher social ability scores possessed enhanced impulsivity control compared with children with lower social ability scores. Moreover, children who held the infant human doll with a LCB had significantly higher mean social ability scores than children who held the infant human doll with a right cradling bias. Those individuals with a predisposition to employ the left visual field for viewing social stimuli may develop enhanced social processing abilities compared with their right cradling biased counterparts. It is important to note that mean scores for both groups of children were representative of a typically developing population. Thus the difference in mean scores may represent two distinct motor/cognitive phenotypes based on laterality of brain function. Further investigations of behavioral biases may hold the key to a better understanding of the links between brain organization and function. Interestingly, the cradling side of only the infant human doll was associated with social ability scores, suggesting that conspecifics cradled on the left are processed with enhanced salience, potentially resulting in enhanced social ability compared with right side cradlers.

Although previous research draws an association between hand dominance and hemispheric lateralization for language (e.g., Knecht et al., 2000), and reports suggest

that as child hand dominance increases, so does verbal ability (Leask & Crow, 2001), we did not find a relationship between hand dominance and the socio-communication survey scores. For the present investigation, we did not test specifically language ability or vocabulary size. It is likely that the communication survey items did not reflect the elements of language production and comprehension that are sensitive to hand dominance for manual motor tasks that are cited in the literature (see Lindell & Hudry, 2013). Moreover, social and communication ability survey scores were strongly positively correlated, suggesting that these measures may not have revealed discrete cognitive domains.

5. Conclusion

Our results suggest that even the most basic face stimuli can elicit population-level LCB in children, preferentially engaging the left visual field and the right hemisphere. The robust cradling behaviors found across stimuli supports an early developmental or innate predisposition for faces (for a review, see Johnson et al., 2015). However, in some cases, unfamiliar or stressful stimuli can cause the LCB to be reversed. Interestingly, the side of holding for *only* the conspecific face stimuli was associated with social ability scores, suggesting that the exposure to *human* faces is important for social cognitive development in children.

The findings from this study may have reach beyond cradling investigations. Research into specific populations with difficulties perceiving faces have found decreased attention to face stimuli (Jones & Klin, 2013) and disrupted right hemisphere activity during face processing (Keehn, Vogel-Farley, Tager-Flusberg & Nelson, 2015). Individuals diagnosed with autistic spectrum disorders have been reported to demonstrate face processing deficits associated with diminished activation of the right fusiform gyrus (for review, see Curby, Willenbockel, Tanaka & Schultz; 2010) and the absence of a LVF bias for face faces in infants (Dundas, Gastgeb & Strauss, 2012). Going forward, a better understanding of the associations between behavioral biases, brain organization/function and cognitive ability during childhood is important identifying and tracking behavioral phenotypes to allow us to make predictions about developmental trajectories across both typical and atypical populations.

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865 **References**

- 866 1. Alonso, Y. (1998). Lateralization of visual guided behaviour during feeding in zebra
867 finches (*Taeniopygia guttata*). *Behavioural Processes*, 43(3), 257-263.
868 [https://doi.org/10.1016/S0376-6357\(98\)00015-1](https://doi.org/10.1016/S0376-6357(98)00015-1)

2. Anfora, G., Rigosi, E., Frasnelli, E., Ruga, V., Trona, F., & Vallortigara, G. (2011). Lateralization in the invertebrate brain: left-right asymmetry of olfaction in bumble bee, *Bombus terrestris*. *PLoS One*, 6(4), e18903. <https://doi.org/10.1371/journal.pone.0018903>
3. Bates, E., O'Connell, B., Vaid, J., Sledge, P., & Oakes, L. (1986). Language and hand preference in early development. *Developmental Neuropsychology*, 2, 1–15. <https://doi.org/10.1080/87565648609540323>
4. Bell, A. T., & Niven, J. E. (2016). Strength of forelimb lateralization predicts motor errors in an insect. *Biology letters*, 12(9), 20160547. doi:10.1098/rsbl.2016.0547
5. Bogren, L. Y. (1984). Side preference in women and men when holding their newborn child: Psychological background. *Acta Psychiatrica Scandinavica*, 69(1), 13–23. <http://dx.doi.org/10.1111/j.1600-0447.1984.tb04512.x>
6. Bonati, B., Csermely, D., & Sovrano, V. A. (2013). Looking at a predator with the left or right eye: asymmetry of response in lizards. *Laterality*, 18(3), 329-339. <https://doi.org/10.1080/1357650X.2012.673623>
7. Bourne, V., & Todd, B. (2004). When left means right: An explanation of the left cradling bias in terms of right hemisphere specializations. *Developmental Science*, 7(1), 19–24. <http://dx.doi.org/10.1111/j.1467-7687.2004.00318.x>
8. Bower, B. (2001). Faces of perception: It's tough to explain how people so easily tell one face from another. *Science News*, 160(1), 10-12. <http://dx.doi.org/10.2307/4012563>
9. Bundy, R. S. (1979). Effects of infant head position on sides preference in adult handling. *Infant Behavior and Development*, 2, 355–358. [https://doi.org/10.1016/S0163-6383\(79\)80045-4](https://doi.org/10.1016/S0163-6383(79)80045-4)
10. Curby, K., Willenbockel, V., Tanaka, J., Schultz, R., (2010). Face processing in autism: Insights from the perceptual expertise framework. In I. Gauthier, M. Tarr & D. Bub (Eds.), *Perceptual expertise: Bridging brain and behavior*. New York: Oxford University Press.
11. Dagenbach, D., Harris, L. J., & Fitzgerald, H. E. (1988). A longitudinal study of lateral biases in parents' cradling and holding of infants. *Infant Mental Health Journal*, 9(3), 218-234. [http://dx.doi.org/10.1002/1097-0355\(198823\)9:3<218::AID-IMHJ2280090305>3.0.CO;2-D](http://dx.doi.org/10.1002/1097-0355(198823)9:3<218::AID-IMHJ2280090305>3.0.CO;2-D)

- 901 12. de Château, P. (1983). Left-side preference for holding and carrying newborn
902 infants: Parental holding and carrying during the first week of life. *The Journal of*
903 *Nervous and Mental Disease*, 171, 241–245. [http://dx.doi.org/10.1097/00005053-](http://dx.doi.org/10.1097/00005053-198304000-00006)
904 198304000-00006
- 905 13. de Château, P., & Andersson, Y. (1976). Left-side preference for holding and
906 carrying newborn infants: Doll-holding and carrying from 2 to 16 years.
907 *Developmental Medicine and Child Neurology*, 18, 738–744.
908 <http://dx.doi.org/10.1111/j.1469-8749.1976.tb04229.x>
- 909 14. de Château, P., Holmberg, H., & Winberg, J. (1978). Left-side preference in holding
910 and carrying newborn infants. I: mothers holding and carrying during the first
911 week of life. *Acta Paediatrica*, 67, 169–175. [http://dx.doi.org/10.1111/j.1651-](http://dx.doi.org/10.1111/j.1651-2227.1978.tb16298.x)
912 2227.1978.tb16298.x
- 913 15. Demaree, H. A., Everhart, D. E., Youngstrom, E. A., & Harrison, D. W. (2005). Brain
914 lateralization of emotional processing: historical roots and a future incorporating
915 “dominance”. *Behavioral and cognitive neuroscience reviews*, 4(1), 3-20.
916 <https://doi.org/10.1177/1534582305276837>
- 917 16. De Renzi, E., Perani, D., Carlesimo, G. A., Silveri, M. C., Fazio, F. (1994).
918 Prosopagnosia can be associated with damage confined to the right hemisphere –
919 an MRI and PET study and a review of the literature. *Neuropsychologia*, 32, 893–
920 902.
- 921 17. Di Giorgio, E. D., Loveland, J. L., Mayer, U., Rosa-Salva, O., Versace, E., &
922 Vallortigara, G. (2017). Filial responses as predisposed and learned preferences:
923 Early attachment in chicks and babies. *Behavioural Brain Research*, 325, 90-104.
- 924 18. Donnot, J. (2007). Lateralisation of emotion predicts infant-holding bias in left-
925 handed students, but not in left-handed mothers. *Laterality*, 12(3), 216-226.
926 <https://doi.org/10.1080/13576500601182385>
- 927 19. Dundas, E., Gastgeb, H., & Strauss, M.S. (2012). Left visual field biases when
928 infants process faces: A comparison of infants at high- and low-risk for autism
929 spectrum disorder. *Journal of Autism and Developmental Disorders*, 42, 2659–
930 2668.

- 931 20. Fagard, J., & Marks, A. (2000). Unimanual and bimanual tasks and the assessment
932 of handedness in toddlers. *Developmental Science*, 3(2), 137–147.
933 <http://dx.doi.org/10.1111/1467-7687.00107>
- 934 21. Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005).
935 Newborns' preference for face-relevant stimuli: Effects of contrast
936 polarity. *Proceedings of the National Academy of Sciences of the United States of*
937 *America*, 102(47), 17245-17250. <https://doi.org/10.1073/pnas.0502205102>
- 938 22. Fernández-Carriba, S., Loeches, A., Morcillo, A., & Hopkins, W. D. (2002).
939 Functional asymmetry of emotions in primates: new findings in
940 chimpanzees. *Brain Research Bulletin*, 57(3-4), 561-564.
941 [https://doi.org/10.1016/S0361-9230\(01\)00685-2](https://doi.org/10.1016/S0361-9230(01)00685-2)
- 942 23. Forrester, G. S. (2017). Hand, Limb, and Other Motor Preferences. In L. J. Rogers &
943 G. Vallortigara (Eds.), *Lateralized Brain Functions* (pp. 121-152). New York, US:
944 Humana Press. <https://doi.org/10.1007/978-1-4939-6725-4>
- 945 24. Forrester, G. S., Crawley, M., & Palmer, C. (2014). Social environment elicits
946 lateralized navigational paths in two populations of typically developing
947 children. *Brain and cognition*, 91, 21-27.
948 <https://doi.org/10.1016/j.bandc.2014.07.005>
- 949 25. Forrester, G. S., Pegler, R., Thomas, M. S., & Mareschal, D. (2014). Handedness as
950 a marker of cerebral lateralization in children with and without
951 autism. *Behavioural Brain Research*, 268, 14-21.
952 <https://doi.org/10.1016/j.bbr.2014.03.040>
- 953 26. Franklin III, W. E., & Lima, S. L. (2001). Laterality in avian vigilance: do sparrows
954 have a favourite eye? *Animal Behaviour*, 62(5), 879-885.
955 <https://doi.org/10.1006/anbe.2001.1826>
- 956 27. Frasnelli, E., Vallortigara, G., & Rogers, L. J. (2012). Left–right asymmetries of
957 behaviour and nervous system in invertebrates. *Neuroscience & Biobehavioral*
958 *Reviews*, 36(4), 1273-1291. <https://doi.org/10.1016/j.neubiorev.2012.02.006>
- 959 28. Gauthier, I., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). Expertise for cars
960 and birds recruits brain areas involved in face recognition. *Nature Neuroscience*,
961 3(3), 191-7.

- 962 29. Giljov, A., Karenina, K., & Malashichev, Y. (2018). Facing each other: mammal
963 mothers and infants prefer the position favouring right hemisphere
964 processing. *Biology Letters*, 14(1), 20170707.
965 <https://doi.org/10.1098/rsbl.2017.0707>
- 966 30. Ginsburg, H. J., Fling, S., Hope, M. L., Musgrove, D., & Andrews, C. (1979).
967 Maternal holding preferences: a consequence of newborn head-turning
968 response. *Child Development*, 50(1), 280-281. <http://dx.doi.org/10.2307/1129073>
- 969 31. Goren, C., Sarty, M., & Wu, P. (1975). Visual following and pattern discrimination
970 of face-like stimuli by newborn infants. *Pediatrics*, 56, 544–549. PMID: 1165958
- 971 32. Gorno-Tempini, M. L., & Price, C. J. (2001). Identification of famous faces and
972 buildings: a functional neuroimaging study of semantically unique items. *Brain*,
973 124(10), 2087097
- 974 33. Gudmundsson, E. (1993). Lateral preference of preschool and primary school
975 children. *Perceptual and Motor Skills*, 77(3), 819-828.
976 <https://doi.org/10.2466/pms.1993.77.3.819>
- 977 34. Güntürkün, O. (2003). Human behaviour: adult persistence of head-turning
978 asymmetry. *Nature*, 421(6924), 711. doi:10.1038/421711a
- 979 35. Guo, K., Meints, K., Hall, C., Hall, S., & Mills, D. (2009). Left gaze bias in humans,
980 rhesus monkeys and domestic dogs. *Animal cognition*, 12(3), 409-418.
981 <https://doi.org/10.1007/s10071-008-0199-3>
- 982 36. Harris, L. J. (2010). Side biases for holding and carrying infants: Reports from the
983 past and possible lessons for today. *Laterality*, 15(1-2), 56-135.
984 <https://doi.org/10.1080/13576500802584371>
- 985 37. Harris, L. J., Almerigi, J. B., & Kirsch, E. A. (2000). Side preference in adults for
986 holding infants: Contributions of sex and handedness in a test of imagination.
987 *Brain and Cognition*, 43(1-3), 246–252. PMID: 10857703
- 988 38. Harris, L. J., Spradlin, M. P., Jr., & Almerigi, J. B. (2006). Mothers' and fathers'
989 lateral biases for holding their newborn infants: A study of images from the World
990 Wide Web. *Laterality*, 12, 64–86. <https://doi.org/10.1080/13576500600948323>
- 991 39. Hauser, M. D. (1993). Right hemisphere dominance for the production of facial
992 expression in monkeys. *Science*, 261(5120), 475-477.
993 <https://doi.org/10.1126/science.8332914>

- 994 40. Haxby, J. V. & Gobbini, M. I. (2011). Oxford Handbook of Face Perception. In
995 Rhodes, Gillian and Calder, Andy and Johnson, Mark and Haxby, James V. (Eds.) "
996 Oxford University Press.
- 997 41. Hellige, J. B. (1993). Unity of thought and action: Varieties of interaction between
998 the left and right cerebral hemispheres. *Current Directions in Psychological*
999 *Science*, 2(1), 21-26. doi:10.1111/1467-8721.ep10770559
- 1000 42. Hendriks, A. W., van Rijswijk, M., & Omtzigt, D. (2011). Holding-side influences on
1001 infant's view of mother's face. *Laterality*, 16(6), 641-655.
1002 <https://doi.org/10.1080/13576500903468904>
- 1003 43. Hook-Costigan, M. A., & Rogers, L. J. (1998). Lateralized use of the mouth in
1004 production of vocalizations by marmosets. *Neuropsychologia*, 36(12), 1265-1273.
1005 [https://doi.org/10.1016/S0028-3932\(98\)00037-2](https://doi.org/10.1016/S0028-3932(98)00037-2)
- 1006 44. Hopkins, W. D. (2004). Laterality in maternal cradling and infant positional biases:
1007 Implications for the development and evolution of hand preferences in
1008 nonhuman primates. *International Journal of Primatology*, 25(6), 1243-1265.
1009 <https://doi.org/10.1023/B:IJOP.0000043961.89133.3d>
- 1010 45. Hopkins, W. D. (Ed.) (2007). *The evolution of hemispheric specialization in*
1011 *primates* (Vol. 5). American Society of Primatologists. Amsterdam, NL: Academic
1012 Press. ISBN: 978-0-12-374197-4
- 1013 46. Huggenberger, H. J., Suter, S. E., Reijnen, E., & Schachinger, H. (2009). Cradling
1014 side preference is associated with lateralized processing of baby facial expressions
1015 in females. *Brain and Cognition*, 70(1), 67-72.
1016 <https://doi.org/10.1016/j.bandc.2008.12.010>
- 1017 47. Johnson, M. H. (2007). Developing a social brain. *Acta Paediatrica*, 96(1), 3-5.
1018 <http://dx.doi.org/10.1111/j.1651-2227.2006.00037.x>
- 1019 48. Johnson, M. H., Dziurawiec, S., Ellis, H. & Morton, J. (1991). Newborns'
1020 preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, 40,
1021 1-19. [https://doi.org/10.1016/0010-0277\(91\)90045-6](https://doi.org/10.1016/0010-0277(91)90045-6)
- 1022 49. Johnson, M. H., Senju, A., & Tomalski, P. (2015). The two-process theory of face
1023 processing: modifications based on two decades of data from infants and
1024 adults. *Neuroscience & Biobehavioral Reviews*, 50, 169-179.
1025 <https://doi.org/10.1016/j.neubiorev.2014.10.009>

- 1026 50. Jonas, J., Rossion, B., Brissart, H., Frismand, S., Jacques, C., Hossu, G., Colnat-
1027 Coulbois, S., Vespignani, H., Vignal, J. P., Maillard, L. (2015). Beyond the core face-
1028 processing network: Intracerebral stimulation of a face-selective area in the right
1029 anterior fusiform gyrus elicits transient prosopagnosia. *Cortex*, 72, 140-155.
- 1030 51. Jones, S. J. (2017). What is the significance of lefward cradling bias? *Journal of*
1031 *Neonatal Biology*, 6(3), 1-5. [https://doi.org/ 10.4172/2167-0897.1000259](https://doi.org/10.4172/2167-0897.1000259)
- 1032 52. Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2–6-
1033 month-old infants later diagnosed with autism. *Nature*, 504, 427–431.
- 1034 53. Karenina, K., Giljov, A., Ingram, J., Rowntree, V. J., Malashichev, Y. (2017).
1035 Lateralization of mother–infant interactions in a diverse range of mammal
1036 species. *Nature Ecology and Evolution*, 1(2), 0030.
1037 <https://doi.org/10.1038/s41559-016-0030>
- 1038 54. Keehn, B., Vogel-Farley, V., Tager-Flusberg, H., & Nelson, C.A. (2015). Atypical
1039 hemispheric specialization for faces in infants at risk for autism spectrum
1040 disorder. *Autism Research*, 8(2), 187-198.
- 1041 55. Kemp, S. L., Korkman, M., & Kirk, U. (2001). *Essentials of NEPSY assessment* (Vol.
1042 6). New York, US: John Wiley & Sons, Inc. ISBN: 0-471-32690-9
- 1043 56. Knecht, S., Dräger, B., Deppe, M., Bobe, L., Lohmann, H., Flöel, A., Ringelstein, E.
1044 B., & Henningsen, H. (2000). Handedness and hemispheric language dominance in
1045 healthy humans. *Brain*, 123(12), 2512-2518.
1046 <https://doi.org/10.1093/brain/123.12.2512>
- 1047 57. Koboroff, A., Kaplan, G., & Rogers, L. J. (2008). Hemispheric specialization in
1048 Australian magpies (*Gymnorhina tibicen*) shown as eye preferences during
1049 response to a predator. *Brain Research Bulletin*, 76(3), 304-306.
1050 <https://doi.org/10.1016/j.brainresbull.2008.02.015>
- 1051 58. Korkman, M., Kirk, U., Kemp, S. L. (2007). NEPSY-Second edition (NEPSY-II). San
1052 Antonio, TX: The Psychological Corporation.
- 1053 59. Leask, S. J., & Crow, T. J. (2001). Word acquisition reflects lateralization of hand
1054 skill. *Trends in Cognitive Sciences*, 5(12), 513-516. [https://doi.org/10.1016/S1364-](https://doi.org/10.1016/S1364-6613(00)01795-2)
1055 [6613\(00\)01795-2](https://doi.org/10.1016/S1364-6613(00)01795-2)

- 1056 60. Leppanen, J., Moulson, M., Vogel-Farley, V., Nelson, C. (2007). An ERP study of
1057 emotional face processing in the adult and infant brain. *Child Development*, 78(1),
1058 232–245. <https://doi.org/10.1111/j.1467-8624.2007.00994.x>
- 1059 61. Lindell, A. K., & Hudry, K. (2013). Atypicalities in cortical structure, handedness,
1060 and functional lateralization for language in autism spectrum
1061 disorders. *Neuropsychology Review*, 23(3), 257-270.
1062 <http://dx.doi.org/10.1007/s11065-013-9234-5>
- 1063 62. Lippolis, G., Bisazza, A., Rogers, L. J., & Vallortigara, G. (2002). Lateralisation of
1064 predator avoidance responses in three species of toads. *Laterality*, 7(2), 163-183.
1065 <https://doi.org/10.1080/13576500143000221>
- 1066 63. Macchi Cassia, V., Valenza, E., Simion, F., & Leo, I. (2008). Congruency as a
1067 nonspecific perceptual property contributing to newborns' face preference. *Child*
1068 *Development*, 79(4), 807–820. [http://dx.doi.org/10.1111/j.1467-](http://dx.doi.org/10.1111/j.1467-8624.2008.01160.x)
1069 [8624.2008.01160.x](http://dx.doi.org/10.1111/j.1467-8624.2008.01160.x)
- 1070 64. Manning J. T. (1991). Sex differences in left-side infant holding: Results from
1071 “family album” photographs, *Ethology and Sociobiology*, 12(5), 337-343,
1072 [https://doi.org/10.1016/0162-3095\(91\)90029-P](https://doi.org/10.1016/0162-3095(91)90029-P)
- 1073 65. Manning, J. T., & Chamberlain, A. T. (1991). Left-side cradling and brain
1074 lateralization. *Ethology and Sociobiology*, 12(3), 237–244.
1075 [https://doi.org/10.1016/0162-3095\(91\)90006-C](https://doi.org/10.1016/0162-3095(91)90006-C)
- 1076 66. Manning, J. T., & Denman, J. (1994). Lateral cradling preferences in humans
1077 (Homo sapiens): Similarities within families. *Journal of Comparative*
1078 *Psychology*, 108(3), 262. <http://dx.doi.org/10.1037/0735-7036.108.3.262>
- 1079 67. Manning, J. T., Heaton, R., & Chamberlain, A. T. (1994). Left-side cradling:
1080 Similarities and differences between apes and humans. *Journal of Human*
1081 *Evolution*, 26(1), 77-83. <https://doi.org/10.1006/jhev.1994.1005>
- 1082 68. Martín, J., López, P., Bonati, B., & Csermely, D. (2010). Lateralization when
1083 monitoring predators in the wild: a left eye control in the common wall lizard
1084 (*Podarcis muralis*). *Ethology*, 116(12), 1226-1233. [https://doi.org/10.1111/j.1439-](https://doi.org/10.1111/j.1439-0310.2010.01836.x)
1085 [0310.2010.01836.x](https://doi.org/10.1111/j.1439-0310.2010.01836.x)

- 1086 69. Matheson, E. A., & Turnbull, O. H. (1998). Visual determinants of the leftward
1087 cradling bias: A preliminary report. *Laterality*, 3(3), 283-288.
1088 <https://doi.org/10.1080/713754305>
- 1089 70. Morris, R. D., & Hopkins, W. D. (1993). Perception of human chimeric faces by
1090 chimpanzees: Evidence for a right hemisphere advantage. *Brain and*
1091 *Cognition*, 21(1), 111-122. <https://doi.org/10.1006/brcg.1993.1008>
- 1092 71. Nakamichi, M., & Takeda, S. (1995). A child-holding thought experiment: Students
1093 prefer to imagine holding an infant on the left side of the body. *Perceptual and*
1094 *Motor Skills*, 80(2), 687-690. <https://doi.org/10.2466/pms.1995.80.2.687>
- 1095 72. Nishida, T. (1993). Left nipple sucking preference in wild chimpanzees. *Ethology*
1096 *and Sociobiology*, 14(1), 45-51. [https://doi.org/10.1016/0162-3095\(93\)90017-C](https://doi.org/10.1016/0162-3095(93)90017-C)
- 1097 73. Parvizi, J., Jacques, C., Foster, B. L., Withoft, N., Rangarajan, V., Weiner, K. S., Grill-
1098 Spector, K. (2012). Electrical Stimulation of Human Fusiform Face-Selective
1099 Regions Distorts Face Perception. *The Journal of Neuroscience*, 32, 14915–14920
- 1100 74. Peirce, J. W., Leigh, A. E., & Kendrick, K. M. (2000). Configurational coding,
1101 familiarity and the right hemisphere advantage for face recognition in
1102 sheep. *Neuropsychologia*, 38(4), 475-483. [https://doi.org/10.1016/S0028-](https://doi.org/10.1016/S0028-3932(99)00088-3)
1103 [3932\(99\)00088-3](https://doi.org/10.1016/S0028-3932(99)00088-3)
- 1104 75. Pileggi, L.-A., Malcolm-Smith, S., & Solms, M. (2015). Investigating the role of
1105 social-affective attachment processes in cradling bias: The absence of cradling
1106 bias in children with Autism Spectrum Disorders, *Laterality*, 20(2), 154-170.
1107 <https://doi.org/10.1080/1357650X.2014.948449>
- 1108 76. Previc, F. (1991). A general theory concerning the prenatal origins of cerebral
1109 lateralization in humans. *Psychological Review*, 98(3), 299–334.
1110 <http://dx.doi.org/10.1037/0033-295X.98.3.299>
- 1111 77. Quaresmini, C., Forrester, G. S., Spiezio, C., & Vallortigara, G. (2014). Social
1112 environment elicits lateralized behaviors in gorillas (*Gorilla gorilla gorilla*) and
1113 chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, 128(3), 276.
1114 <http://dx.doi.org/10.1037/a0036355>
- 1115 78. Reid, V. M., Dunn, K., Young, R. J., Amu, J., Donovan, T., & Reissland, N. (2017).
1116 The human fetus preferentially engages with face-like visual stimuli. *Current*
1117 *Biology*, 27(12), 1825-1828. <https://doi.org/10.1016/j.cub.2017.05.044>

- 1118 79. Reissland, N. (2000). The cradling bias in relation to pitch of maternal child-
1119 directed language. *British Journal of Developmental Psychology*, 18(2), 179-186.
1120 <https://doi.org/10.1348/026151000165634>
- 1121 80. Reissland, N., Hopkins, B., Helms, P., & Williams, B. (2009). Maternal stress and
1122 depression and the lateralization of infant cradling. *The Journal of Child*
1123 *Psychology and Psychiatry*, 50(3), 263–269. [https://doi.org/10.1111/j.1469-](https://doi.org/10.1111/j.1469-7610.2007.01791.x)
1124 7610.2007.01791.x
- 1125 81. Richards, J. L., Finger, S. (1975). Mother-child holding patterns: a cross-cultural
1126 photographic survey. *Child Development*, 56(4), 1001-1004.
1127 <http://dx.doi.org/10.2307/1128413>
- 1128 82. Rodriguez, A., Kaakinen, M., Moilanen, I., Taanila, A., McGough, J. J., Loo, S., &
1129 Järvelin, M. R. (2010). Mixed-handedness is linked to mental health problems in
1130 children and adolescents. *Pediatrics*, 125(2), e340-e348.
1131 <https://doi.org/10.1542/peds.2009-1165>
- 1132 83. Rogers, L. J. (2000). Evolution of hemispheric specialization: advantages and
1133 disadvantages. *Brain and language*, 73(2), 236-253. [https://doi.org/10.1006/](https://doi.org/10.1006/brln.2000.2305)
1134 brln.2000.2305
- 1135 84. Rogers, L. J. (2002). Lateralization in vertebrates: its early evolution, general
1136 pattern, and development. *Advances in the Study of Behavior*, 31, 107-161.
1137 [https://doi.org/10.1016/S0065-3454\(02\)80007-9](https://doi.org/10.1016/S0065-3454(02)80007-9)
- 1138 85. Rogers, L. J., & Andrew, R. (Eds.) (2002). *Comparative vertebrate lateralization*.
1139 Cambridge, UK: Cambridge University Press. ISBN: 9780521787000
- 1140 86. Rogers, L. J., Vallortigara, G., & Andrew, R. J. (2013). Divided brains: the biology
1141 and behaviour of brain asymmetries. Cambridge, UK: Cambridge University Press.
1142 <https://doi.org/10.1017/CBO9780511793899>
- 1143 87. Rosa Salva, O., Farroni, T., Vallortigara, G., & Johnson, M. H. (2011). The Evolution
1144 of Social Orienting: Evidence from Chicks (*Gallus gallus*) and Human Newborns.
1145 *PLoS ONE*, 6(4), e18802
- 1146 88. Rutledge, R., & Hunt, G. R. (2004). Lateralized tool use in wild New Caledonian
1147 crows. *Animal Behaviour*, 67(2), 327-332.
1148 <https://doi.org/10.1016/j.anbehav.2003.07.002>

- 1149 89. Saling, M., & Bonert, R. (1983). Lateral cradling preferences in female
1150 preschoolers. *The Journal of Genetic Psychology: Research and Theory on Human*
1151 *Development*, 142(1), 149-150.
1152 <http://dx.doi.org/10.1080/00221325.1983.10533505>
- 1153 90. Salk, L. (1973). The role of the heartbeat in the relations between mother and
1154 infant. *Scientific American*, 228(5), 24–29. doi:10.1038/scientificamerican0573-24
- 1155 91. Scola, C., & Vauclair, J. (2010a). Is infant holding-side bias related to motor
1156 asymmetries in mother and child? *Developmental psychobiology*, 52(5), 475-486.
1157 <https://doi.org/10.1002/dev.20450>
- 1158 92. Scola, C., & Vauclair, J. (2010b). Infant holding side biases displayed by fathers in
1159 maternity hospitals. *Journal of reproductive and Infant Psychology*, 28(1), 3–10.
1160 <https://doi.org/10.1080/02646830903190938>
- 1161 93. Scott, S. K., Sauter, D., & McGettigan, C. (2010). Brain mechanisms for processing
1162 perceived emotional vocalizations in humans. In S.M. Brudzynski *Handbook of*
1163 *mammalian vocalization: an integrative neuroscience approach* (Vol. 19, pp. 187-
1164 198). London, UK: Academic. [https://doi.org/10.1016/B978-0-12-374593-](https://doi.org/10.1016/B978-0-12-374593-4.00019-X)
1165 [4.00019-X](https://doi.org/10.1016/B978-0-12-374593-4.00019-X)
- 1166 94. Sieratzki, J. S., & Woll, B. (1996). Why do mothers cradle babies on their left? *The*
1167 *Lancet*, 347(9017), 1746-1748.
- 1168 95. Sieratzki, J. S., & Woll, B. (2002). Neuropsychological and neuropsychiatric
1169 perspectives on maternal cradling preferences. *Epidemiology and Psychiatric*
1170 *Sciences*, 11(3), 170-176. <https://doi.org/10.1017/S1121189X00005686>
- 1171 96. Sieratzki, J. S., & Woll, B. (2004). The impact of maternal deafness on cradling
1172 laterality with deaf and hearing infants. *Journal of deaf studies and deaf*
1173 *education*, 9(4), 387-394. <https://doi.org/10.1093/deafed/enh052>
- 1174 97. Sieratzki, J. S., Roy, P., & Woll, B. (2002). Left cradling and left ear advantage for
1175 emotional speech: Listen to the other side too. *Laterality*, 7(4), 351-353.
1176 <https://doi.org/10.1080/13576500143000276>
- 1177 98. Simion, F., Macchi Cassia, V., Turati, C., & Valenza, E. (2001). The origins of face
1178 perception: specific versus non-specific mechanisms. *Infant and Child*
1179 *Development*, 10(1-2), 59-65. <https://doi.org/10.1002/icd.247>

- 1180 99. Souza-Godoli, M. R. C. (1996). Lateral cradling preferences in children. *Perceptual*
1181 *and Motor Skills*, 83, 1421–1422.
- 1182 100. Suter, S. E., Huggenberger, H. J., & Schächinger, H. (2007). Cold pressor stress
1183 reduces left cradling preference in nulliparous human females. *The International*
1184 *Journal on the Biology of Stress*, 10(1), 45–51.
1185 <https://doi.org/10.1080/10253890601141259>
- 1186 101. Szaflarski, J. P., Rajagopal, A., Altaye, M., Byars, A. W., Jacola, L., Schmithorst, V. J.,
1187 Schapiro, M. B., Plante, E., & Holland, S. K. (2012). Left-handedness and language
1188 lateralization in children. *Brain Research*, 1433, 85–97.
1189 <https://doi.org/10.1016/j.brainres.2011.11.026>
- 1190 102. Thompson, A. M., & Smart, J. L. (1993). A prospective study of the development of
1191 laterality: Neonatal laterality in relation to perinatal factors and maternal
1192 behavior. *Cortex*, 29(4), 649–659. [https://doi.org/10.1016/S0010-9452\(13\)80288-](https://doi.org/10.1016/S0010-9452(13)80288-2)
1193 2
- 1194 103. Todd, B. K., & Banerjee, R. (2016). Lateralization of infant holding by mothers: A
1195 longitudinal evaluation of variations over the first 12 weeks. *Laterality*, 21(1), 12–
1196 33. <https://doi.org/10.1080/1357650X.2015.1059434>
- 1197 104. Todd, B. K., Barry, J. A. & Thommessen, S. A. O. (2017). Preferences for ‘Gender-
1198 typed’ Toys in Boys and Girls Aged 9 to 32 Months. *Infant and Child Development*,
1199 26(3).
- 1200 105. Todd, B. K., Fischer, R. A., Di Costa, S., Roestorf, A., Harbour, K., Hardiman, P., &
1201 Barry, J. A. (2018). Sex differences in children's toy preferences: A systematic
1202 review, meta-regression, and meta-analysis. *Infant and Child Development*, 27(2),
1203 n/a. doi:10.1002/icd.2064
- 1204 106. Toga, A. W., & Thompson, P. M. (2003). Mapping brain asymmetry. *Nature*
1205 *Reviews Neuroscience*, 4(1), 37. <https://doi.org/10.1038/nrn1009>
- 1206 107. Tomaszycski, M., Cline, C., Griffin, B., Maestripieri, D., & Hopkins, W. D. (1998).
1207 Maternal cradling and infant nipple preferences in rhesus monkeys (*Macaca*
1208 *mulatta*). *Developmental Psychobiology*, 32(4), 305–312.
1209 [http://dx.doi.org/10.1002/\(SICI\)1098-2302\(199805\)32:4<305::AID-](http://dx.doi.org/10.1002/(SICI)1098-2302(199805)32:4<305::AID-DEV5>3.0.CO;2-R)
1210 DEV5>3.0.CO;2-R

1211 108.Turnbull, O. H., & Bryson, H. E. (2001). The leftward cradling bias and hemispheric
1212 asymmetry for speech prosody. *Laterality*, 6(1), 21-28.
1213 <https://doi.org/10.1080/713754394>

1214 109.Turnbull, O. H., & Lucas, M. D. (1991). Lateral cradling preferences in males: The
1215 relationship to infant experience. *The Journal of genetic psychology*, 152(3), 375-
1216 376. <https://doi.org/10.1080/00221325.1991.9914694>

1217 110.Turnbull, O. H., Rhys-Jones, S. L., & Jackson, A. L. (2001). The leftward cradling
1218 bias and prosody: An investigation of cradling preferences in the deaf
1219 community. *The Journal of genetic psychology*, 162(2), 178-186.
1220 <https://doi.org/10.1080/00221320109597959>

1221 111.Turnbull, O., Lucas, M. (1996). Is the leftward cradling bias related to lateral
1222 asymmetries in attention? *The Journal of Genetic Psychology*, 157(2), 161–167.
1223 <https://doi.org/10.1080/00221325.1996.9914854>

1224 112.Umiltà, C., Simion, F., & Valenza, E. (1996). Newborn's preference for
1225 faces. *European Psychologist*, 1(3), 200-205. [https://doi.org/10.1027/1016-](https://doi.org/10.1027/1016-9040.1.3.200)
1226 [9040.1.3.200](https://doi.org/10.1027/1016-9040.1.3.200)

1227 113.Valenza, E., Leo, I., Gava, L., & Simion, F. (2006). Perceptual completion in
1228 newborn human infants. *Child Development*, 77(6), 1810-1821.
1229 <http://dx.doi.org/10.1111/j.1467-8624.2006.00975.x>

1230 114.Vallortigara, G. (2000). Comparative neuropsychology of the dual brain: a stroll
1231 through animals' left and right perceptual worlds. *Brain and Language*, 73(2), 189-
1232 219. <https://doi.org/10.1006/brln.2000.2303>

1233 115.Vallortigara, G., & Rogers, L. J. (2005). Survival with an asymmetrical brain:
1234 advantages and disadvantages of cerebral lateralization. *Behavioral and Brain*
1235 *Sciences*, 28(4), 575-588. <https://doi.org/10.1017/S0140525X05350102>

1236 116.van der Meer, A., Husby, A. (2006). Handedness as a major determinant of
1237 functional cradling bias. *Laterality*, 11(3), 263–276.
1238 <https://doi.org/10.1080/13576500500513565>

1239 117.Vauclair, J., & Donnot, J. (2005). Infant holding biases and their relations to
1240 hemispheric specializations for perceiving facial
1241 emotions. *Neuropsychologia*, 43(4), 564-571.
1242 <https://doi.org/10.1016/j.neuropsychologia.2004.07.005>

1243 118.Vauclair, J., & Scola, C. (2009). Infant-holding biases in mothers and affective
1244 symptoms during pregnancy and after delivery. *Infant and Child*
1245 *Development*, 18(2), 106-121. <http://dx.doi.org/10.1002/icd.594>

1246 119.Vallortigara, G., Versace, E. (2017). Laterality at the Neural, Cognitive, and
1247 Behavioral Levels. In "APA Handbook of Comparative Psychology: Vol. 1. Basic
1248 Concepts, Methods, Neural Substrate, and Behavior", J. Call (Editor-in-Chief), pp.
1249 557-577, American Psychological Association, Washington DC.).

1250 120.Vervloed, M. P., Hendriks, A. W., & van den Eijnde, E. (2011). The effects of
1251 mothers' past infant-holding preferences on their adult children's face processing
1252 lateralisation. *Brain and Cognition*, 75(3), 248-254.
1253 <https://doi.org/10.1016/j.bandc.2011.01.002>

1254 121.Wallez, C., & Vauclair, J. (2011). Right hemisphere dominance for emotion
1255 processing in baboons. *Brain and Cognition*, 75(2), 164-169.
1256 <https://doi.org/10.1016/j.bandc.2010.11>

1257 122.Westergaard, G. C., & Suomi, S. J. (1996). Hand preference for a bimanual task in
1258 tufted capuchins (*Cebus apella*) and rhesus macaques (*Macaca mulatta*). *Journal*
1259 *of Comparative Psychology*, 110(4), 406. [http://dx.doi.org/10.1037/0735-](http://dx.doi.org/10.1037/0735-7036.110.4.406)
1260 [7036.110.4.406](http://dx.doi.org/10.1037/0735-7036.110.4.406)

1261 123.Woll, B., & Sieratzki, J. S. (2002). Leftward cradling bias, prosodic speech, and
1262 deafness: the deaf are not dumb. *The Journal of Genetic Psychology*, 163(1), 126-
1263 128. <https://doi.org/10.1080/00221320209597973>

1264 124.Yovel, G. (2016). Neural and cognitive face-selective markers: An integrative
1265 review. *Neuropsychologia*, 83, 5–13.

1266 125.Yovel, G., Tambini, A., Brandman, T. (2008). The asymmetry of the fusiform face
1267 area is a stable individual characteristic that underlies the left-visual-field
1268 superiority for faces. *Neuropsychologia*, 46, 3061–3068.